

[0036] Fabrication

[0037] Various thin film deposition techniques such as e-beam evaporation, sputtering and chemical vapor deposition can be used to produce the multilayer structure described herein. Multiphoton processes involving the surface plasmon in nanoparticles and on planar surfaces show that the quantized nature of the mechanism is most prominent in the case of the localized collective mode in nanoparticles. The photon absorption and relaxation of photoexcited electrons in small nanoparticles can be controlled by changing particle shape and size and tuning the surface plasmon resonance in and out. While detailed knowledge about the dynamics of the optical and electronic properties of nanometer-sized metal particles is lacking, performance in this context is enhanced by the formation of metal surface irregularities in the nm or tens of nm.

[0038] Recent advancements in the chemical synthesis and deposition techniques of metal nanostructures of various shapes such as rods, shells, cups, rings, disks, and cubes, and development of deep submicron lithographic methods for fabricating nanostructure grids and arrays provide the tools for exploiting plasmon properties of metal nanostructures of arbitrary geometry in plasmonic devices, including photovoltaics.

[0039] In one embodiment, silver nanoparticles can be chemically synthesized using a technique based on solution chemistry. One example is to use the reaction between sodium borohydride (or a similar hydride) and silver nitrate solutions of concentration in the vicinity of 0.001M. Polyvinyl pyrrolidone (or a similar water-soluble polymer) can be used to prevent silver particle aggregation. Evaporation of the solution mix yields a layer of silver nanoparticles, for example, in the range of about 1-50 nm.

[0040] A second approach is based on physical deposition in a vacuum environment. A solid metal target is vaporized using resistive heating or bombarded by a laser, or an ion or electron beam to generate Ag vapor. The vapor is then deposited on the desired substrate or the device layer to form a layer of metal nanoparticles. In a specific embodiment, forming a nanostructured silver layer can be achieved by a relatively simple and consistent method of film deposition and processing, which offers the flexibility of manufacturing high-performance devices with a range of size scales. The approach is based on ultrafast pulsed laser deposition, which can be optimized for nanostructured material fabrication. An ultrafast laser pulse can ionize and vaporize a precursor target material without causing significant target melting. The homogeneous precursor vapor is deposited onto a substrate with precise temperature control. Depending on the temperature history of the laser-produced and ionized vapor, different size nanoparticles, for example, in the range of about 1-50 nm start to form either before or after the vapor arrives at the substrate surface. One unique benefit of using an ultrafast laser beam is the process is that material-independent; ultrafast laser ablation does not depend on the thermal properties of the material, offering unprecedented control of the fabrication process.

Alternative Embodiments

[0041] While the embodiments of the invention are primarily described and illustrated in the context of nanostructured silver as the metal electron source on n-TiO₂, as the semiconductor of the Schottky diode, other metal electron sources and semiconductor materials may be used. The metal should be an electron source with surface plasmon resonance within the

visible and near-visible spectrum range (e.g., from about 300 to 1000 nm). Suitable metals include silver, gold, copper and alloys of silver, gold and copper with each other. Silver is preferred for its advantageous opto-electronic properties, relatively low cost, and simplicity of processing.

[0042] The selection of the metal electron source and semiconductor should be coordinated so that a Schottky barrier formed at their interface is lower than the energy of the hot electrons formed in the metal by incident solar energy, but high enough so that electrons that cross the barrier are unable to cross back over. Possible alternative wide-band gap semiconductors include Si, GaN, SiC, CdTe, AsGa etc.

[0043] Conclusion

[0044] The theoretical efficiency of a surface plasmon-enhanced photovoltaic device as described herein is as high as 50%. The materials used are plentiful and inexpensive. Thin film deposition techniques have been in use in manufacturing for many years. Given the description provided herein, it is straightforward to adapt and scale up production of these hot electron photovoltaic devices to manufacturing levels. In addition, fabrication techniques such as ultrafast pulsed laser deposition provide scalability and ease of manufacture with the potential for full automation. Finally, this fundamentally different approach to photovoltaic technology offers interesting and promising alternative to the traditional technology. It presents a true technological breakthrough, which may open avenues to future technologies of solar energy conversion.

[0045] Although the foregoing invention has been described in some detail for purposes of clarity of understanding, certain changes and modifications will be apparent to those of skill in the art. It should be noted that there are many alternative ways of implementing both the process and materials and apparatuses of the present invention. Accordingly, the present embodiments are to be considered as illustrative and not restrictive, and the invention is not to be limited to the details given herein.

What is claimed:

1. An electronic device comprising:

- a metal electron source layer comprising a nanostructured metal surface having a surface plasmon resonance within the visible and near-visible spectrum range;
- a semiconductor layer in contact with the metal electron source layer, wherein the metal electron source layer and the semiconductor layer form an interface that is a Schottky barrier; and
- an electrode layer in contact with the semiconductor layer, wherein the electrode layer forms an ohmic contact to the semiconductor layer.

2. The device of claim 1, wherein metal electron source layer is a nanostructured metal layer having a surface plasmon resonance within the visible and near-visible spectrum range.

3. The device of claim 2, wherein the nanostructured metal layer comprises silver.

4. The device of claim 3, wherein the nanostructured metal layer is silver.

5. The device of claim 3, wherein the nanostructured metal layer is a silver alloy.

6. The device of claim 5, wherein the silver alloy comprises another metal selected from the group consisting of copper, gold and a combination thereof.

7. The device of claim 1, wherein the nanostructured metal layer comprises gold.